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POPULATIONS AND PREY SELECTION OF WINTERING RAPTORS IN BOULDER COUNTY, COLORADO

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Abstract. Wintering raptor populations were monitored between 1983 and 1988 in a 35 km² study area centered 8 km north-northeast of the city of Boulder, Colorado. Raptors congregated around active prairie dog (*Cynomys* sp.) colonies. Golden eagles (*Aquila chrysaetos*), ferruginous hawks (*Buteo regalis*), and red-tailed hawks (*Buteo jamaicensis*) were observed hunting and capturing prairie dogs. Bald eagles (*Haliaeetus leucocephalus*) and northern harriers (*Circus cyaneus*) participated in the competition for captured prey. Thirteen occurrences were noted of bald eagles stealing captured prairie dogs from ferruginous hawks. A bubonic plague outbreak killed most of the prairie dogs within the study area in 1986, corresponding with a > 60% decline in numbers of wintering bald eagles, ferruginous hawks and red-tailed hawks. A bald eagle winter roost that had been occupied by 40 eagles prior to the plague outbreak was abandoned the following winter.

Key Words. raptors, prairie dog, ferruginous hawk, bald eagle, red-tailed hawk, Colorado

INTRODUCTION

Explorers and settlers of the High Plains were astonished by the abundance of black-tailed prairie dogs (*Cynomys ludovicianus*) and the variety of wildlife that congregated around prairie dog colonies. Francis Parkman (1949), who crossed the High Plains in 1846, noted that prairie dog colonies along the Platte River "teemed with wildlife." Hal Borland (1956), whose family homesteaded in eastern Colorado in 1910, said the local prairie dog town appeared to have "... attracted half the hawks and coyotes and badgers in the county."

These early reports notwithstanding, the importance of prairie dogs as a food source for predators, particularly raptors, has not been determined. Grossman and Moore (1987) said that predation appears to have a minor impact on black-tailed prairie dog colonies in Wind Cave National Park, South Dakota. Campbell and Clark (1981) and Clark *et al.* (1982), who studied prairie dog-raptor associations in Colorado, Wyoming, Utah, and New Mexico, reported that golden eagles (*Aquila chrysaetos*), ferruginous hawks (*Buteo regalis*), and Swainson's hawks (*Buteo swainsoni*) hunted prairie dogs, but their research found no evidence of predation by red-tailed hawks (*Buteo jamaicensis*) or great horned owls (*Bubo virginianus*). Several observers suggested that red-tailed hawks are not large enough to effectively prey on prairie dogs (Bent 1937, Longhurst 1944, King 1955). On the other hand, Blumstein (1986) found prairie dog remains in pellets collected from three of four red-tailed hawk nests located within 1 km of active prairie dog colonies in Boulder County, Colorado. D'Ostilio (1954) reported that prairie dogs were the third most common prey item found in golden eagle nests in central Colorado, and Imler (1937) found evidence of predation on prairie dogs by bald eagles (*Haliaeetus leucocephalus*) wintering in western Kansas.

This study investigated raptor-prairie dog associations in Boulder County, Colorado, over a five-year period. The goals were to determine the extent of predation on prairie dogs by various raptor species and to note how fluctuations in prairie dog populations corresponded with fluctuations in wintering raptor populations.

STUDY SITE

The study was conducted within a 35 km² area centered approximately 8 km north-northeast of the city of Boulder in Boulder

County, Colorado. The study area is bounded to the southeast by the Boulder-Longmont Diagonal Highway (Colorado 119), to the west by the Dakota Hogback (the easternmost line of foothills) and to the north by Left Hand Creek. Elevations range from 1,675-1,793 m. The area contains mixed prairie, lowland riparian, foothills shrub and sedge-cattail wetland ecosystems. Approximately 120 ha of wetlands occur around several small lakes and reservoirs. Prior to a bubonic plague outbreak in 1985-86, 17 active prairie dog colonies, which varied in size from 5 ha to 100 ha, occupied an estimated 8.2% of the study area. Land uses include agricultural grazing, rural residential, idle land, and agricultural cropland. About 80% of the land within the study area is privately owned; the remainder is undeveloped park land owned and managed by the City of Boulder.

Great horned owls, burrowing owls (*Athene cunicularia*), and red-tailed hawks nest within the study area. A pair of Swainson's hawks nested 3 km to the south during the summers of 1986 and 1987. A golden eagle eyrie, located in the foothills 2 km west of the study area, has been active since 1882 (Jollie 1943, Figs and Lederer 1986).

METHODS

A 19 km long survey route, beginning and ending near Boulder Reservoir, was established in September 1983. This route was surveyed four to seven times each year from 15 September through 14 November and five to eight times each year from 15 November through 14 March during 1983-1988. The survey route was driven at 40 km/hour, and stops were made every 3.2 km. As raptors were sighted, their position was marked on a seven and one-half minute topographic map. Raptors that could not be identified were not included in the data base.

Between November 1982 and January 1984, pellets and bone fragments were collected from beneath wooden fence posts at Boulder Valley Ranch, a 5 km² wildlife preserve within the study area that is owned by the city of Boulder. Teeth and jaw fragments were analyzed to identify prey species.

Throughout the study period, anecdotal records were kept of raptor-prey interactions. Seven trips were made to a bald eagle roost along Left Hand Creek to observe hunting behaviors of bald eagles and ferruginous hawks.

During 1986-87, volunteers drove additional survey routes throughout Boulder County. These routes were 22-60 km long and were surveyed 5-13 times from 15 September through 15 March. Data from these survey routes and from the Boulder Audubon Christmas Bird Counts (Kaempfer 1986, 1987) were compared to data collected within the study area. Estimates of prairie dog populations along these survey routes were derived from the Boulder County Health Department's 1987 census of prairie dog colonies in Boulder County (Boulder County Health Department 1987). From 1984 to 1988, visual estimates were made of the size of prairie dog colonies within the study area.

RESULTS AND DISCUSSION

Raptor Migration Patterns

The fall raptor migration in Boulder County begins in early September and reaches its peak in early October (Boulder Audubon

Society 1987). Migrating raptors ride the thermals that rise up over the eastern foothills of the Rocky Mountains. Freeman Hall, who counted migrating raptors in Boulder County from 1982-88, observed as many as 30 raptors per hour from an observation point 3 km north of the study area during late September and early October (F. Hall, personal communication).

Arrival times for wintering raptors probably are related to a number of factors, including the availability of prey along the migration route and seasonal weather patterns (Craighead and Craighead 1956). Red-tailed hawks, sharp-shinned hawks (*Accipiter striatus*), and Cooper's hawks (*Accipiter cooperii*) reach peak numbers in September and October, while ferruginous hawks, rough-legged hawks, and bald eagles usually arrive later (Boulder Audubon Society 1987).

Mean raptor density per trip, per month was compiled for the Boulder Reservoir survey route from 1983-88 (Table 1). Red-tailed hawks were the first raptors to arrive in the study area in large numbers. During September, October, and November, they comprised 45% of all raptors observed. The highest number of red-tailed hawks observed on a single survey was 21 on 28 September, 1985. During most years, ferruginous hawks began to appear in the study area in October with mean ferruginous hawk density reaching a peak in November. Ferruginous hawks were relatively abundant during the winter months of December, January, and February, when they comprised 30% of all raptors observed. The highest number of ferruginous hawks observed on a single survey was 17 on 24 November 1985. Bald eagles usually arrived in the study area in November and stayed through February. The highest number of bald eagles observed on a single survey was 8 on 3 February 1985. Small numbers of rough-legged hawks and northern harriers were present throughout the study period. The highest number of rough-legged hawks observed on a single survey was 4 on 17 February 1985. The highest number of northern harriers observed on a single survey was 4 on 1 January 1984.

Species diversity (mean number of sightings within a given month) was greater during the winter months of December, January, and February (8.0 per month) than during the fall months of September, October and November (6.7 per month). During the winter months red-tailed hawks and ferruginous hawks comprised 51% of all raptors observed. During the fall months these species comprised 67% of all raptors observed.

Prey and Habitat Selection

Association of raptors with prairie dog colonies was examined by plotting the location, by habitat, of all raptors observed along the survey route from 1983-1987 (Table 2). Habitats were divided

into 3 categories: "wetland," including marshes, lakes and reservoirs, "prairie dog colony," and "other." Raptors were placed in the "wetland" and "prairie dog colony" categories if they were initially sighted perched or soaring within the given habitat or within 50 m of its margins. All other raptors were placed in the "other" category.

Aggregations of ferruginous hawks, red-tailed hawks, and bald eagles were frequently observed in the vicinity of prairie dog colonies. During the winters of 1984-85 and 1985-85, 13 instances were noted of bald eagles taking prairie dogs from ferruginous hawks. Kleptoparasitism of ferruginous hawks by red-tailed hawks (4 instances) and by northern harriers (1 instance) was also observed throughout the study period.

Table 3 compares the size of prairie dog colonies and the number of perches within each colony or within 50 m of each colony with the total number of raptors sighted within each colony. Only prairie dog colonies immediately adjacent to the survey route were included. The data were analyzed using the correlation coefficient (r) and the true range of the correlation coefficient (ρ) at the 0.95 confidence interval. Correlations for which the range of ρ includes zero are not statistically significant. The correlation between number of perches and number of raptors ($r = 0.94$, $0.75 < \rho < 0.98$) was stronger than the correlation between prairie dog colony size and number of raptors ($r = 0.85$, $0.48 < \rho < 0.96$). All of the 5 prairie dog colonies where bald eagles were sighted ranked high in number of perches. Four of these colonies (Table 3: 34-1, 34-2, 34-3 and 34-4) were situated within 2 km of the bald eagle roost on Left Hand Creek.

Possibilities for observer error must be taken into account in these calculations. Since raptors perched on trees or telephone poles are probably easier to see than those soaring in the air or perched on the ground, observations from a survey route that passes on the periphery of prairie dog colonies may tend to overestimate the importance of perches. Observations from the survey route may tend to underestimate the importance of prairie dog colony size, since some raptors perched in large prairie dog colonies may be at the limit of observer visibility.

Pellets and bone fragments collected from within 1 m of the base of wooden fence posts at Boulder Valley Ranch yielded jawbone fragments and teeth of 37 black-tailed prairie dogs, 34 voles (*Microtus* sp.), 11 cottontail rabbits (*Sylvilagus* sp.), 10 mice (*Peromyscus* sp.), 2 birds, 1 muskrat (*Ondatra zibethicus*), and 1 domestic cat (*Felis domestica*). These fenceposts were used as perches by golden eagles, bald eagles, ferruginous hawks, red-tailed hawks, rough-legged hawks, and great horned owls. Pellet

Table 1. Mean number of raptors per trip by month on Boulder Reservoir survey route.¹

Species	Sept. (11) ²	Oct. (11)	Nov. (11)	Dec. (8)	Jan. (8)	Feb. (7)	Mar. (1)
	----- number/trip -----						
Northern harrier	0.30	0.43	0.50	0.75	0.75	0.22	0.00
Rough-legged hawk	0.20	0.43	0.80	0.75	1.16	1.89	1.00
Ferruginous hawk	0.30	1.78	4.50	2.25	3.25	3.56	1.00
Red-tailed hawk	4.40	4.43	4.60	1.38	2.75	2.00	1.00
Bald eagle	0.00	0.00	0.70	1.63	0.50	2.56	0.00
Golden eagle	0.30	0.50	0.20	0.13	0.25	0.56	0.00
Prairie falcon	0.00	0.07	0.00	0.00	0.00	0.22	0.00
American kestrel	1.60	2.64	1.20	0.75	1.08	1.11	0.00
Short-eared owl	0.00	0.00	0.00	0.13	0.42	0.00	0.00
Total	7.10	10.27	12.50	7.77	10.16	12.12	3.00

¹Total number of raptors counted over the 5-year interval divided by total number of trips for given month.

²Number of trips per month.

analysis cannot present a true quantitative picture of prey consumed, since bones of smaller prey may be totally digested by some raptors, and the manner of pellet collection and analysis invariably biases the results (Errington 1932). Nevertheless, the number of black-tailed prairie dog remains found among these pellets and bone fragments suggests a high incidence of predation.

Population Trends

Between 1983 and 1985, when the prairie dog population within the study area was slowly expanding (Table 5), numbers of red-tailed hawks, ferruginous hawks, and bald eagles increased dramatically (Table 4). During the winter and spring of 1986, a bubonic plague outbreak killed most of the prairie dogs within the study area (Boulder County Health Department 1987). After the plague incident, numbers of red-tailed hawks, ferruginous hawks, and bald eagles declined sharply, whereas numbers of rough-legged hawks remained constant.

The observed decline in numbers of selected raptors within the study area after the winter of 1985-86 is confirmed by Boulder Audubon Christmas Count results for 1985 and 1986 (Kaempfer

1987). Bald eagle sightings fell from 36 on the 1985 Christmas Count (all within the study area) to 5 on the 1986 count (3 within the study area). Buteo sightings fell from 91 on the 1985 count (45 within the study area) to 78 on the 1986 count (27 within the study area).

During the winters of 1984-85 and 1985-86, bald eagles roosted within the study area in a cottonwood grove along Left Hand Creek. The creek was almost dry during the winter months, but the roost was situated in the midst of several active prairie dog colonies. As many as 40 bald eagles were observed flying into this roost on winter evenings. After the bubonic plague outbreak of 1985-86, the roost was abandoned. No bald eagles were observed at this roost during the winters of 1986-87 and 1987-88.

Mean raptor density and prairie dog density were computed for 5 additional survey routes in Boulder County. These routes were surveyed between 15 September and 15 March 1986-87 (Table 5). Mean density of ferruginous hawks was highest along the 2 survey routes (Marshall and South County) with the highest prairie dog densities. Prairie dog densities for all routes in 1986-87 and for the Boulder Reservoir survey route in 1984-85, 1985-86 and 1986-87 were plotted against mean raptor density for each route. A positive correlation existed between prairie dog density per survey route and mean raptor density per survey route ($r = 0.93, 0.60 < \rho < 0.98$); between prairie dog density and mean ferruginous hawk density ($r = 0.93, 0.60 < \rho < 0.98$); and between prairie dog density and mean red-tailed hawk density ($r = 0.91, 0.55 < \rho < 0.97$). A significant positive correlation did not exist between prairie dog density and mean bald eagle density ($r = 0.68, -0.05 < \rho < 0.93$); or between prairie dog density and mean rough-legged hawk density ($r = 0.25, -0.52 < \rho < 0.78$).

The absence of a significant correlation between prairie dog density and mean bald eagle density suggests that the bald eagles overwintering in the study area during 1984-85 and 1985-86 may have been attracted to the area by factors other than high prairie dog density. These factors could include the presence of numerous lakes and marshes, the availability of suitable perching and roosting sites, and the abundance of other prey species. Since kleptoparasitism can be a primary means of prey acquisition by wintering bald eagles (Brockman and Barnard 1979, Griffin, 1981, Stallmaster and Gessaman 1984), the density of ferruginous hawks in the vicinity of prairie dog colonies may also influence bald eagle selection of prairie dog colonies as foraging sites. Mean ferruginous hawk densities for the South County and Marshall survey

Table 2. Raptor sitings (%) by habitat,¹ 1984-1987

Species	Siting Location			N
	Prairie Dog			
	Wetland ²	Colony	Other	
	----- % -----			
Northern harrier	50	30	20	10
Rough-legged hawk	27	33	40	33
Ferruginous hawk	8	66	26	123
Red-tailed hawk	14	38	48	116
Bald eagle	6	34	60	68
Golden eagle	0	25	75	8
Prairie falcon	0	40	60	5
Short-eared owl	100	0	0	5

¹Soaring or perched in the given habitat or within 50 m of its boundaries.
²"Wetlands" includes cattail and sedge marshes, lakes and reservoirs.

Table 3. Prairie dog colony attributes and total sightings of selected species, 1984-1987.

Colony Number	Area (ha) ¹	Perches ²	Red-tailed hawk	Ferrug. hawk	Rough-legged hawk	Bald eagle	Total
----- number of sightings -----							
6-1	6	6	3	6	1	0	10
4-1	8	5	0	0	0	0	0
34-1	8	18	6	4	2	5	17
3-1	9	0	0	0	0	0	0
30-1	11	7	2	1	0	0	3
34-2	11	18	1	7	1	2	11
34-3	13	21	3	11	0	2	16
34-4	15	16	5	8	2	4	19
31-1	28	0	2	1	1	0	4
5-1	45	14	6	10	0	1	17
31-2	100	40	13	21	4	0	38

¹Maximum area of each colony, 1984-87.

²Number of telephone poles or trees taller than 5 m within each colony or within 50 m of its boundaries.

routes during 1986-87 (0.07 km and 0.11 km) were considerably lower than mean ferruginous hawk densities for the Boulder Reservoir survey route during 1984-85 and 1985-86 (0.18/km and 0.26/km).

This study did not examine the proportion of prairie dogs in raptor diets. Through analysis of pellets collected from roost sites and detailed field observations of foraging raptors, future studies may be able to ascertain more precisely the extent of predation on prairie dogs by raptors. Another issue needing further study is the relation of prairie dog colony attributes such as size, location, and density to wintering raptor population density. Identification of prairie dog colony attributes that correspond with high wintering raptor population densities may become an important management tool for preserving or enhancing wintering raptor habitat on the High Plains.

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Table 4. Mean density (number of sightings/trip) of raptors along Boulder Reservoir survey route, 1983-1987.

Species	1983-84	1984-85	1985-86	1986-87	1987-88
-----number of sightings/trip-----					
Red-tailed hawk	2.3	4.2	5.6	2.4	1.5
Ferruginous hawk	1.5	3.4	4.9	1.1	1.2
Rough-legged hawk	0.5	1.0	1.1	1.0	0.6
Northern harrier	1.5	0.3	0.9	0.0	0.1
Golden eagle	0.1	0.8	0.4	0.1	0.1
Bald eagle	0.0	1.5	2.1	0.1	0.1

Table 5. Mean density of raptors (number/kilometer) along all survey routes.¹

Survey route	Year	Prairie dog density ¹	Red-tailed hawk	Ferrug. hawk	Rough-legged hawk	Bald eagle	Total
-----number/kilometer-----							
Boulder Res.	1984-85	7.59	0.22	0.18	0.05	0.08	0.53
Boulder Res.	1985-86	8.24	0.29	0.26	0.06	0.11	0.72
Boulder Res.	1986-87	0.03	0.13	0.06	0.05	0.01	0.25
Table Mt.	1986-87	0.97	0.08	0.00	0.02	0.02	0.12
N. St. Vrain	1986-87	1.67	0.09	0.06	0.05	0.05	0.25
Lagerman Res.	1986-87	0.44	0.09	0.04	0.05	0.06	0.24
South County	1986-87	3.72	0.13	0.07	0.11	0.01	0.32
Marshall	1986-87	3.36	0.11	0.11	0.08	0.01	0.31

¹Percent of land occupied by active prairie dog colonies within 2.6 km² land sections intersected by survey route.